Agent-based model simulation and its potential features

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Agent-based model

Simulation technique

- It is a bottom-up simulation technique where we analyze a system by its individual agents that interact with each other.
- It has uses in biology, social sciences, traffic management, and supply chain management amongst many other disiplines.
- One of its major benefit is the ability to see how micro-scale behavior impacts the overall system

Bassel Karami, "Intro to Agent Based Modeling", Towards Data Science, 17 Oct 2021, url https://towardsdatascience.com/3eea6a070b72 [20221216].

Elements of ABM

- A set of agents, their attributes and behavious.
- A set of agent relationships and methods of interaction: An underlying topology of connectedness defines how and with whom agents interact.
- The agents' environment: Agents interact with their environment in addition to other agents.

C. M. Macal, M. J. North, "Tutorial on agent-based modelling and simulation", Journal of Simulation, vol 4, no 3, p 151-162, Sep 2010, url https://doi.org/10.1057/jos.2010.3.

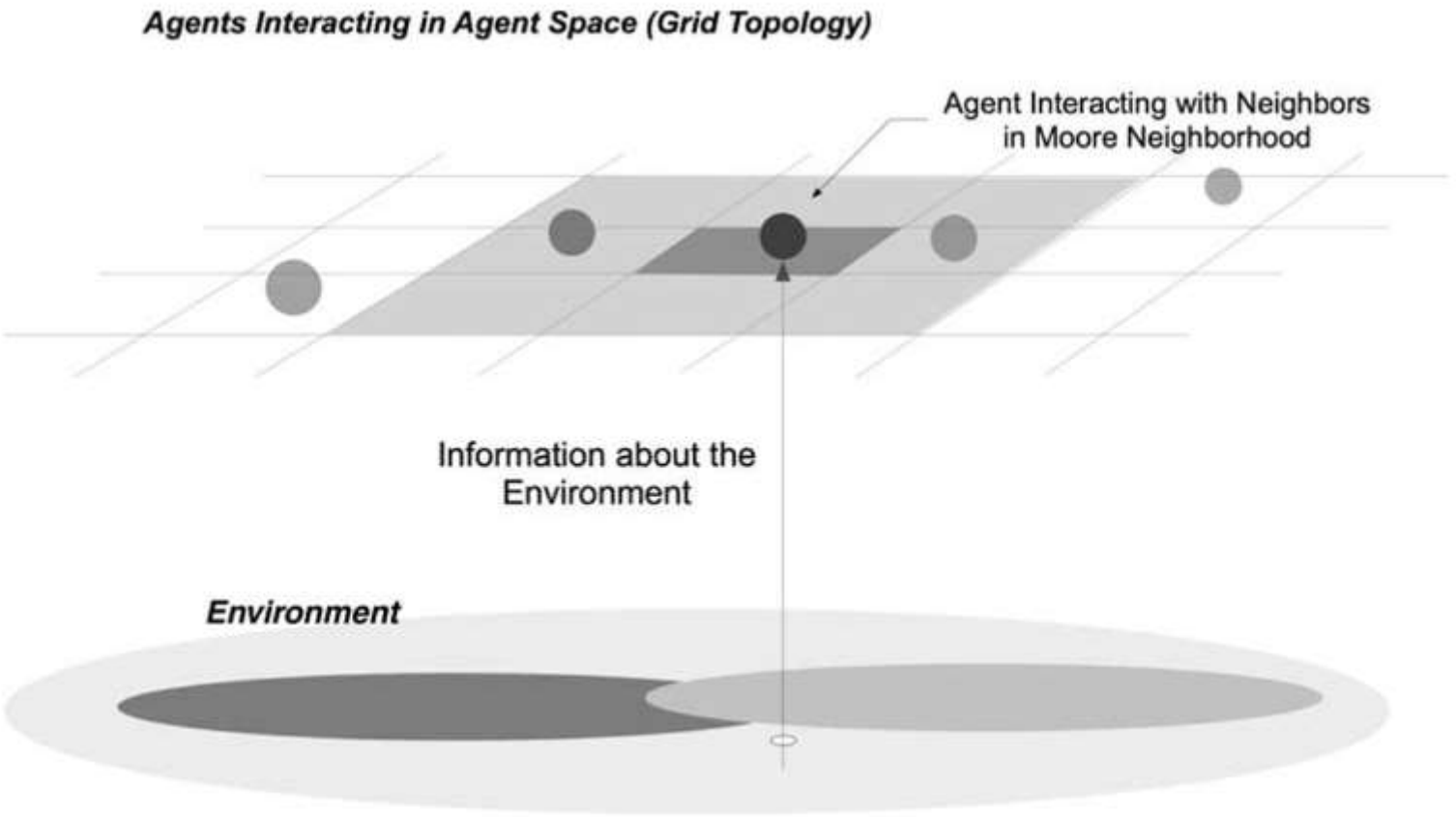


Figure 1 The structure of a typical agent-based model, as in Sugarscape (Epstein and Axtell, 1996).

Emergent behaviours

- ABM is commonly used to analyze complex systems, which are characterized by a large variety of components that interact with each other, and It attempts to replicate the behaviour of the actors in these systems to better understand them and potentially increase their performance.
- It can produce patterns, structures, and behaviours that were not explicitly programmed into the models, but arise through the agent interaction [1].

Stef Janssen, Alexei Sharpanskykh, Richard Curran, Koen Langendoen, "Using causal discovery to analyze emergence in agent-based models", Simulation Modelling Practice and Theory, vol 96, p 101940, Nov 2019, url https://doi.org/10.1016/j.simpat.2019.101940.

Parallelization

- ABM can run on a single processor machine.
- It can also be using parallelisation of agent models run on multi-core hardware.
- Second approach requires modification of the implementation, which produces result in large improvements in model efficiency (speed and memory use).

Hazel R. Parry, Mike Bithell, "Large Scale Agent-Based Modelling: A Review and Guidelines for Model Scaling", in Heppenstall, A., Crooks, A., See, L., Batty, M. (eds) Agent-Based Models of Geographical Systems, Springer, Dordrecht, p 217-308, url https://doi.org/10.1007/978-90-481-8927-4_14.

Physics: Phases of matter

A particle in a grid

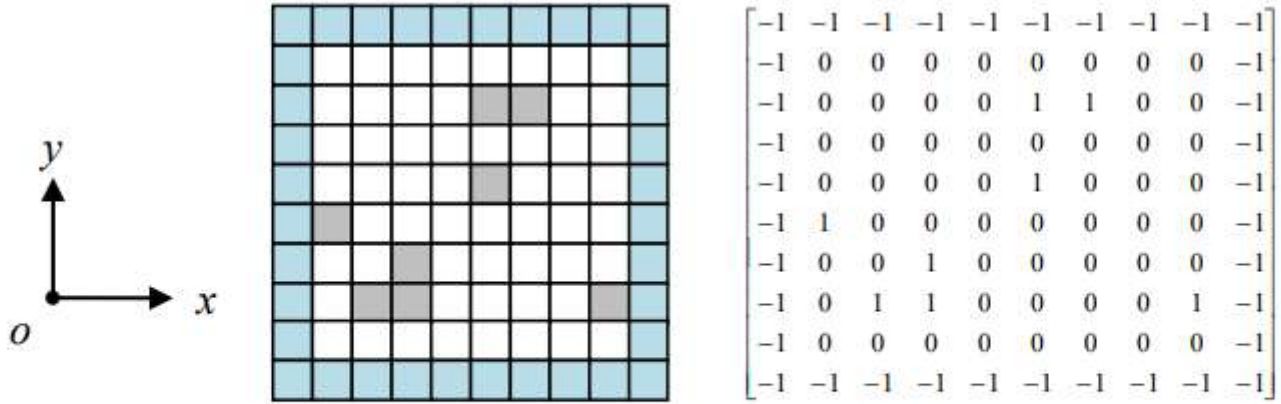


Figure 1. A system of particles in a 10×10 grid constrained by a surrounding wall and consisted of eight agents: a visual representation (left) and its matrix representation (right).

S. Viridi, F. Haryanto, "Agent-based Model and its Potential in Simulating Some Physical Systems", IOP Conference Series: Materials Science and Engineering 559 (1), 012008 (2019), url https://doi.org/10.1088/1757-899X/599/1/012008.

Direction of motion

Table 1. Allowed moving direction for agents.

Direction	Abbreviation	Number
↑	NO (north)	0
↗	NE (northeast)	1
→	EA (east)	2
↘	SE (southeast)	3
↓	SO (south)	4
↙	SW (southwest)	5
←	WE (west)	6
↖	NW (northwest)	7

Probability for each direction

3.1. Single phase system (G = 1)

There are four types of system phase that can be obtained using $\mathbf{P}_{1\times1}$, which are solid, liquid, gas, and granular

$$\mathbf{P}_{1\times1} = [P_{sp}], \tag{10}$$

with probability vector single phase P_{sp} are

$$P_{\text{Sol}} = [0.000 \quad 0.000 \quad 0.000 \quad 0.000 \quad 1.000 \quad 0.000 \quad 0.000 \quad 0.000], \tag{11}$$

$$P_{\text{Liq}} = [0.060 \quad 0.110 \quad 0.110 \quad 0.125 \quad 0.250 \quad 0.125 \quad 0.110 \quad 0.110], \tag{12}$$

$$P_{\text{Gas}} = [0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125], \tag{13}$$

$$P_{\text{Gra}} = [0.000 \quad 0.000 \quad 0.000 \quad 0.250 \quad 0.500 \quad 0.250 \quad 0.000 \quad 0.000]. \tag{14}$$

Implementation of equations (11) – (14) and the results are given in figure 2.

Common phases of matter

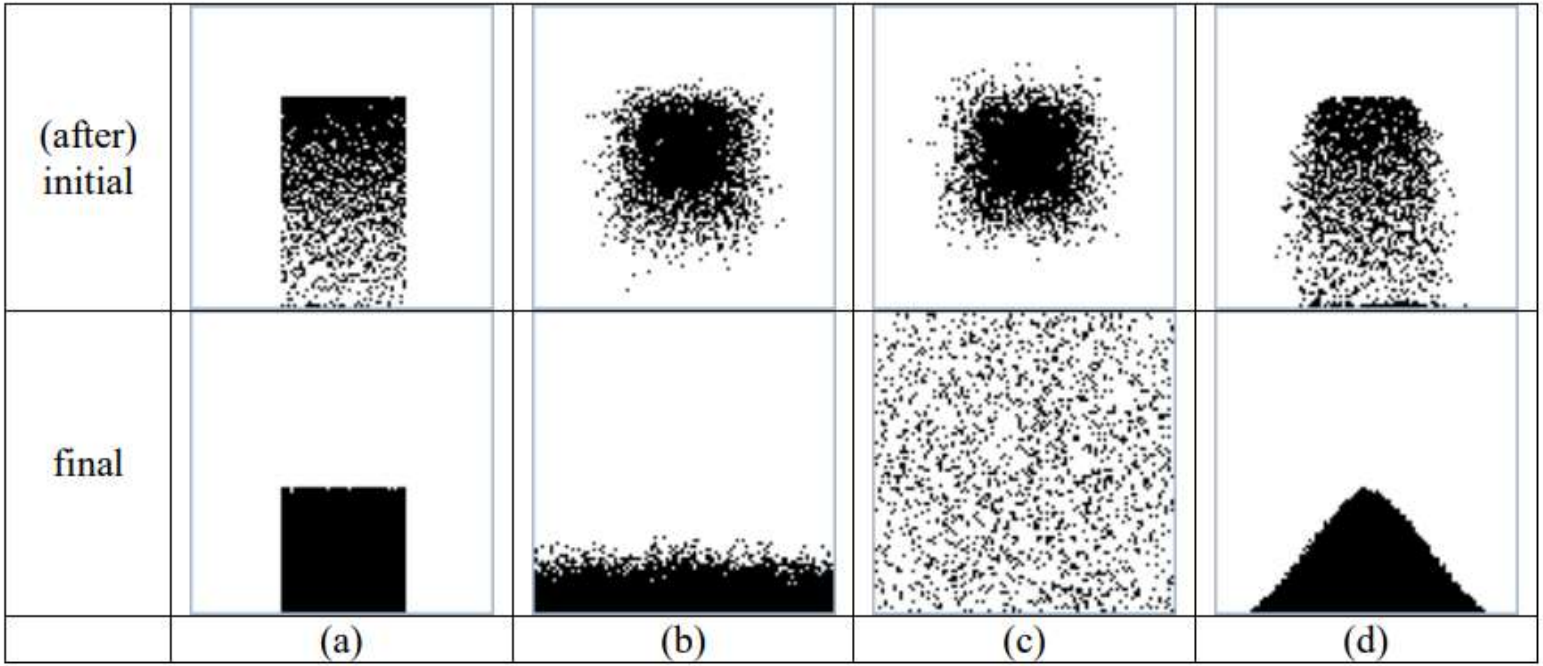


Figure 2. Single phase system (after) initial and final state for various types of materials (a) solid, (b) liquid, (c) gas, and (d) granular.

Biology: Cell budding

Cell reproduction

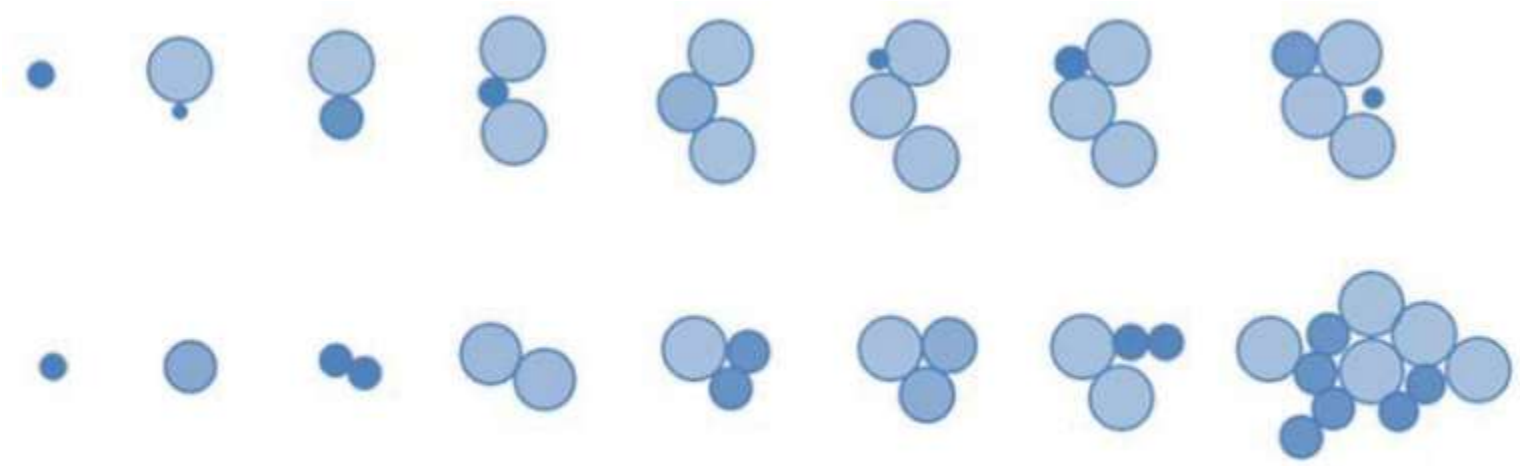


FIGURE 2. Cell asexual reproduction: budding (top row) and binary division (bottom row).

S. Viridi, A. D. Mauluda, S. H. Pratama, Suprijadi, "Simulation of cell budding and binary fission: A preliminary study using molecular dynamics and agent-based model", in 2020 International Conference and School on Physics in Medicine and Biosystem: Physics Contribution in Medicine and Biomedical Applications, (ICSPMB)-2020, edited by Lukmanda Evan Lubis, Nur Aisyah Nuzulia, Nur Rahmah Hidayati, AIP Conference Proceedings 2346, American Institute of Physics, Melville, NY, 2021, pp. 020010, url https://doi.org/10.1063/5.0048209.

Algorithms: Cell budding

STEP 1 Begin.
STEP 2 Choose a cell from list of cells in the system.
STEP 3 Increase cell age.
STEP 4 If cell age $< T_{mature}$ grow the cell.
STEP 5 If cell age $\neq T_{mature} + nT_{budding}$, $n = 0, 1, 2$, proceed with STEP 1.
STEP 6 Generate random position on the surface of mother cell for budding site.
STEP 7 Create new daughter cell on the budding site.
STEP 8 Add the new cell to the list of cells.
STEP 9 Proceed to STEP 2 and repeat until all the cells are processed.
STEP 10 End.

Algorithms: Cell binary division

STEP 1 Begin.
STEP 2 Choose a cell from list of cells in the system.
STEP 3 Increase cell age.
STEP 4 If cell age $< T_{mature}$ grow the cell.
STEP 5 If cell age $\neq T_{mature} + nT_{budding}$, $n = 0, 1, 2$, proceed with STEP 1.
STEP 6 Generate random orientation for two identical cells position inside the mother cell.
STEP 7 Delete mother cell and remove it from the list.
STEP 8 Create two identical daughter cells with generated positions.
STEP 9 Add the new cells to the list of cells.
STEP 10 Proceed to STEP 2 and repeat until all the cells are processed.
STEP 11 End.

Number of cells and colony size

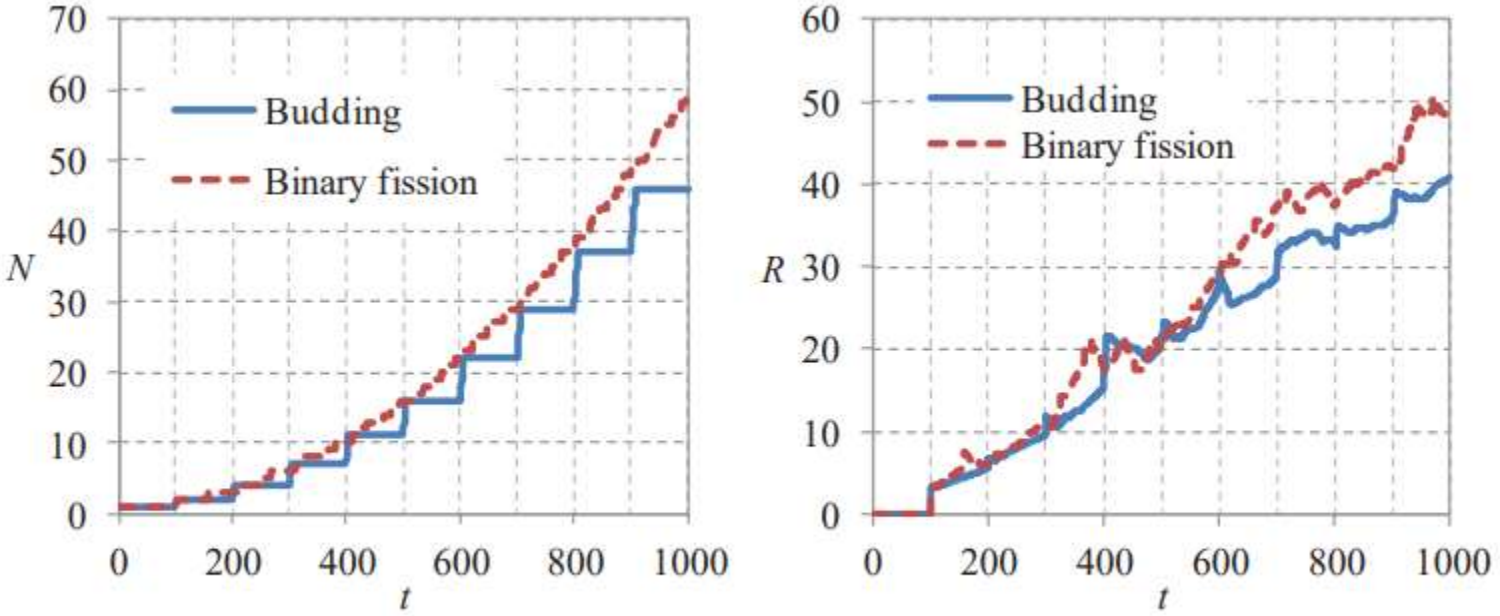


FIGURE 4. Number of cells N (left) and colony radius R (right).

Health: Infection spread

SIR model

Normalized and discrete form of SIR differential equations can be written in the forms of

$$s_{i+1} = s_i - \beta s_i i_i , \quad (1)$$

$$i_{i+1} = i_i + \beta s_i i_i - \gamma i_i , \quad (2)$$

$$r_{i+1} = r_i + \gamma i_i , \quad (3)$$

where s_i, i_i, and r_i stand for fraction number of susceptible, infected, and recovered person of the population at iteration i, respectively. Since s_i, i_i, and r_i are fraction number, they must obey

$$s_i + i_k + r_i = 1 , \quad (4)$$

Armi Susandi, Intan Taufik, Pingkan Aditiawati, Sparisoma Viridi, "The relation between agent-based model and susceptible-infected-recovered model for spread of disease", in The 9th National Physics Seminar, (SNF)-2020, edited by Hadi Nasbey, Riser Fahdiran, Widyaningrum Indrasari, Esmar Budi, Fauzi Bakri, Teguh Budi Prayitno, Dewi Muliyati, AIP Conference Proceedings 2320, American Institute of Physics, Melville, NY, 2021, pp. 050032, url https://doi.org/10.1063/5.0038221.

Dynamics (but only in a point)

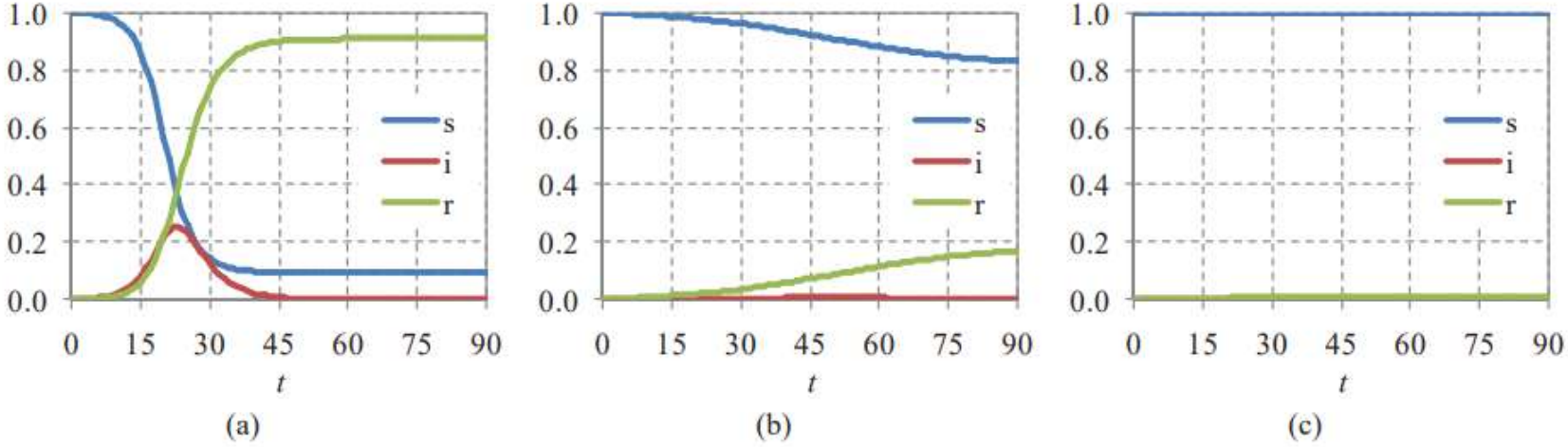


FIGURE 1. Dynamics of s, i, and r with $\beta = 0.6$ and R_0: (a) 2.5, (b) 1.1, (c) 0.8.

Agents in separate cities

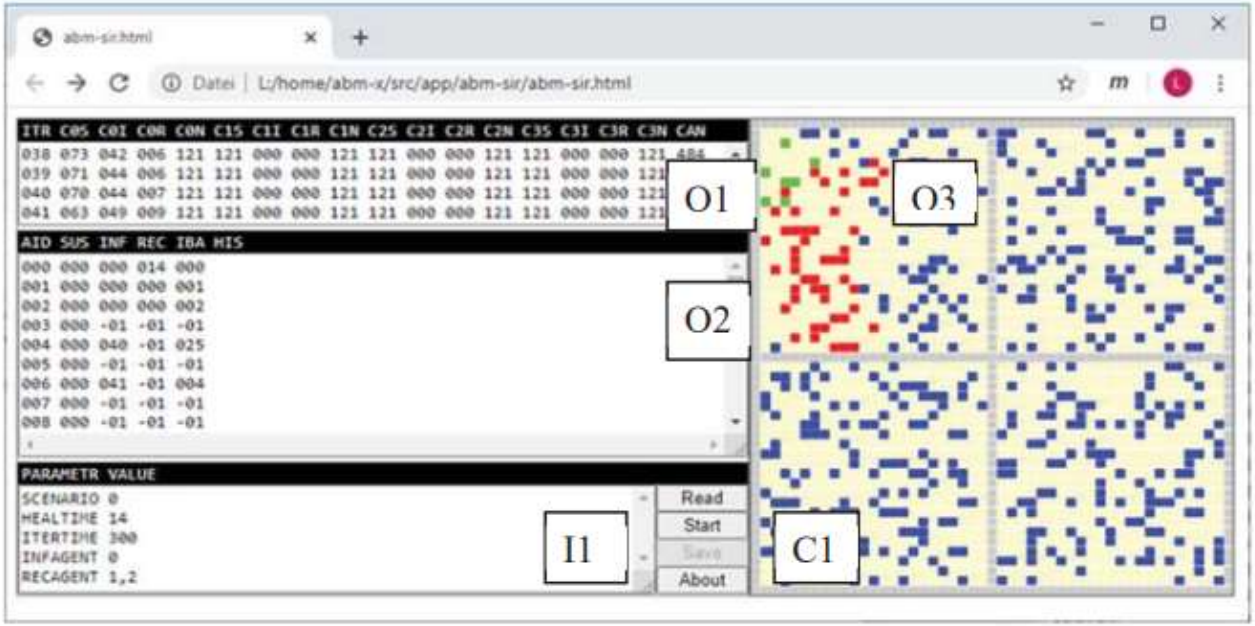


FIGURE 2. User interface of `abm-sir` simulation with one input section (I1) and three output sections (O1, O2 O3), and a control section (C1).

Theory vs simulation

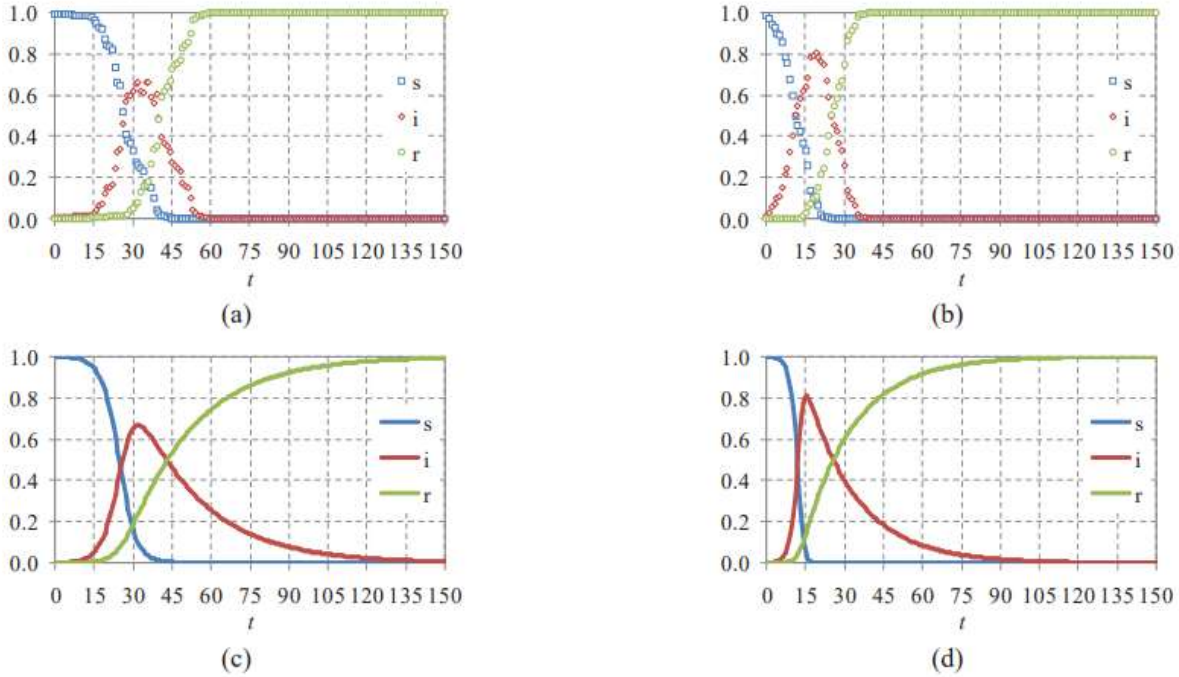


FIGURE 6. Infection stages of the system with one infected agent in the corner: (a) ABM, (c) SIR; and in the center: (b) ABM, (d) SIR.

Second wave (emergent pattern)

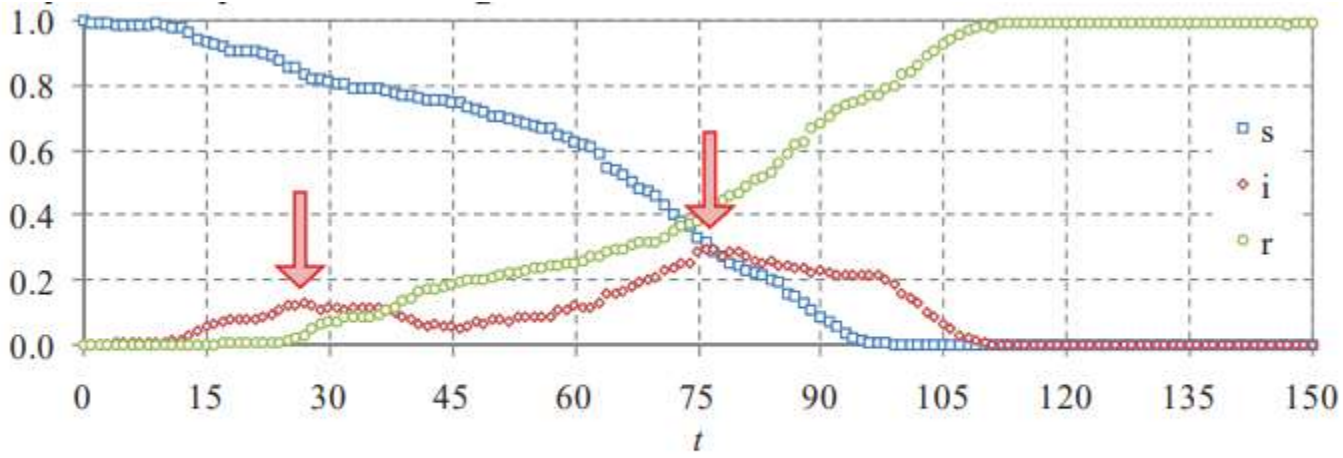


FIGURE 9. Aggregate infection stages of the system with one infected agent in the corner through four connected cities, which is considered as one region.

Transportation: Origin-Destination Matrix

Origin-desination matrix

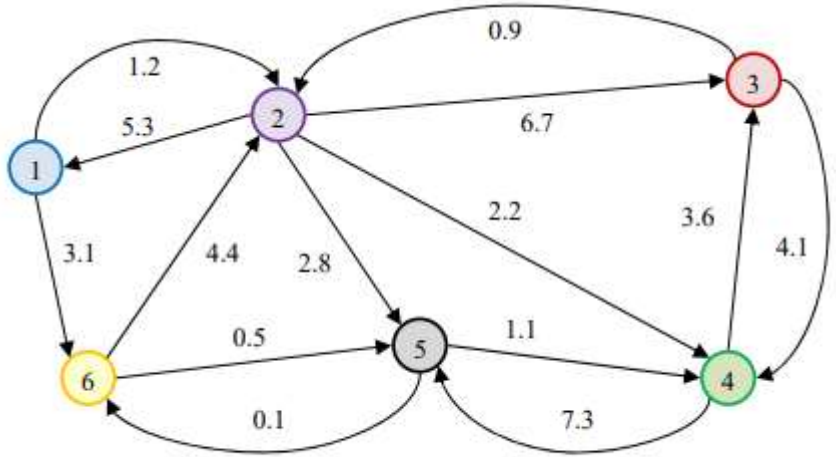


FIGURE 1. A network consists of six nodes and fourteen links.

$$\mathbf{M}_{O-D} = \begin{bmatrix} 0 & 1.2 & 0 & 0 & 0 & 3.1 \\ 5.3 & 0 & 6.7 & 2.2 & 2.8 & 0 \\ 0 & 0.9 & 0 & 4.1 & 0 & 0 \\ 0 & 0 & 3.6 & 0 & 7.3 & 0 \\ 0 & 0 & 0 & 1.1 & 0 & 0.1 \\ 0 & 4.4 & 0 & 0 & 0.5 & 0 \end{bmatrix}$$

T. Suheri, S. Viridi, "Constructing origin-destination matrix (ODM) using agent-based model (AMB) in multiple points commuting system", in The 9th National Physics Seminar, (SNF)-2020, edited by Hadi Nasbey, Riser Fahdiran, Widyaningrum Indrasari, Esmar Budi, Fauzi Bakri, Teguh Budi Prayitno, Dewi Muliyati, AIP Conference Proceedings 2320, American Institute of Physics, Melville, NY, 2021, pp. 050033, url https://doi.org/10.1063/5.0038214.

Simulation

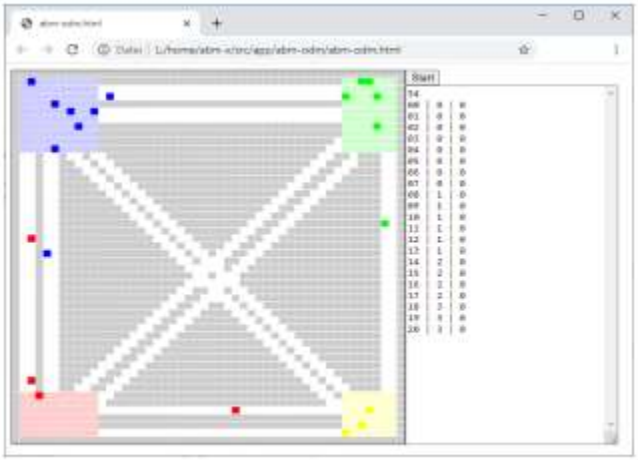


FIGURE 2. User interface of abm-odm based on JS running inside Google Chrome.

Initial conditions (ICs)

The three different initial conditions in Fig. 3 is characterized only with number of agents in each city as shown in following Tab. 3.

TABLE 3. Simulation initial condition.

Name	Number of Initial Agents				Simulation Repetion	Population
	C0	C1	C2	C3		
IC0	8	6	4	3	10	low (21)
IC1	16	12	8	6	10	medium (42)
IC2	32	20	16	10	10	high (78)

Last column in Tab. 3 is only for referring the initial condition in the further discussion, while relating the condition with physical meaning when comparing number of agents and the total space in a city region.

Commuting pattern (emergent behaviour)

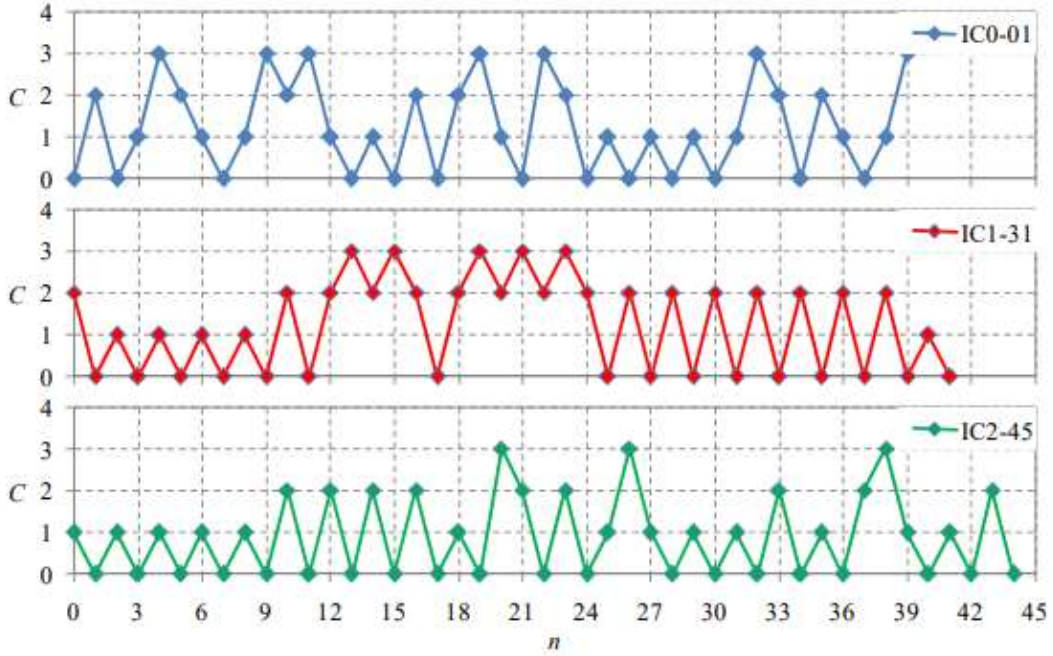


FIGURE 6. Example of agents visited city C for each n-th visit: IC0 with agent 01 (top), IC1 with agent 31 (middle), and IC2 with agent 45 (bottom).

Economics: Rest area customer analysis

Rest area along a highway

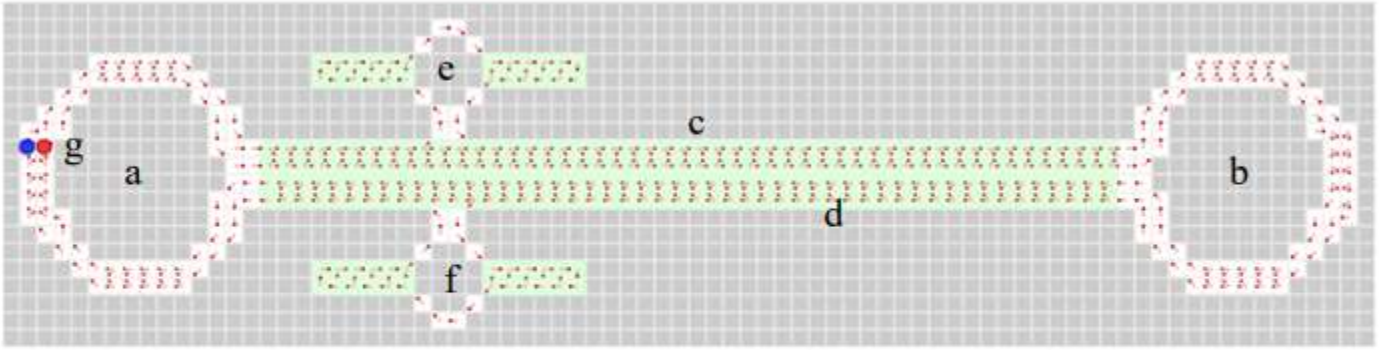


Figure 1. Simulation system consists of some parts: (a) city A, (b) city B, (c) highway from A to B, (d) highway from B to A, (e) rest area in the way from A to B, and (f) rest area in the way from B to A, and (g) two different types of agent.

T. Suheri, S. Viridi, "Gravity-Driven Agent-Based Model for Simulation of Economic Growth a Point Along a Highway", IOP Conference Series: Materials Science and Engineering 662 (6), 062015 (2019), url https://doi.org/10.1088/1757-899X/662/6/062015.

Scenarios' initial configurations

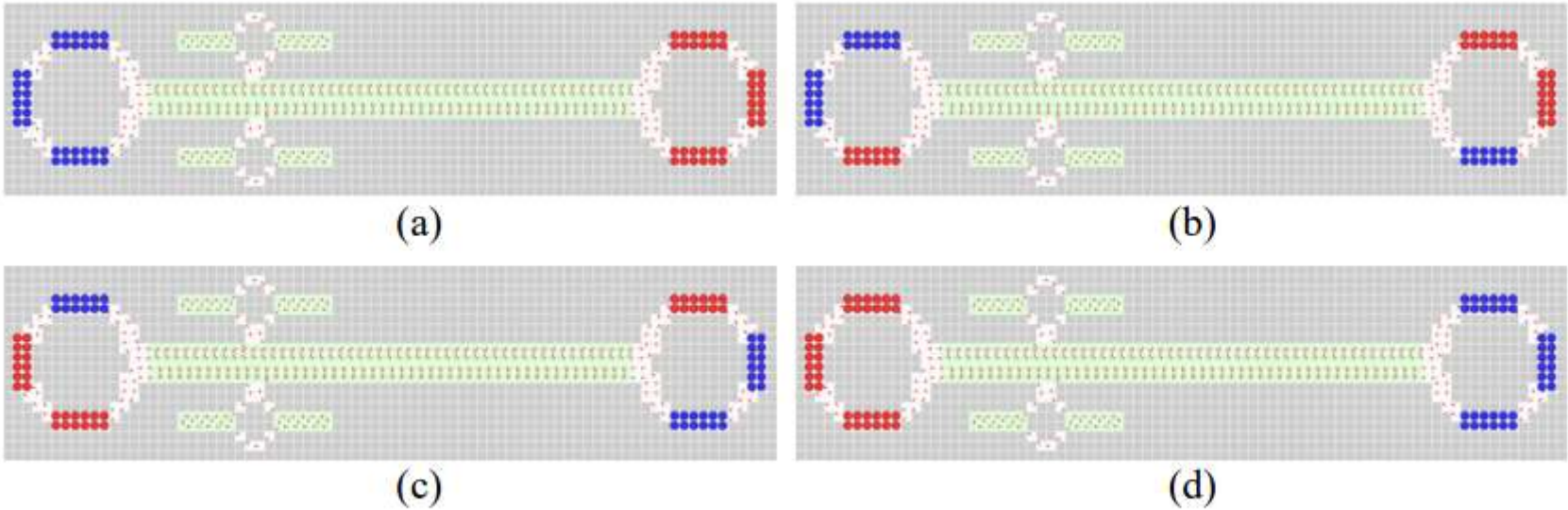


Figure 2. Initial configuration of agents, with different behaviour: without need to visit rest area (blue) and with the need (red), for scenario (a) 0, (b) 1, (c) 2, (d) 3.

Mid configurations

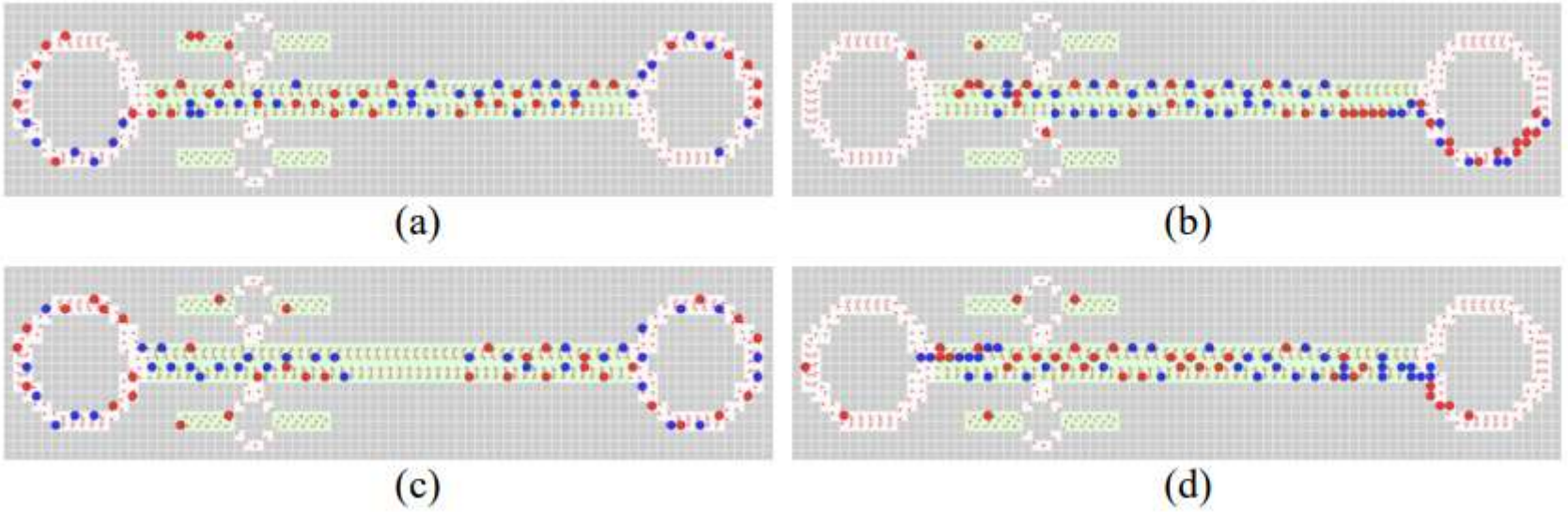


Figure 3. Mid configuration of agents, about three weeks, for scenario (a) 0, (b) 1, (c) 2, (d) 3.

Final configurations

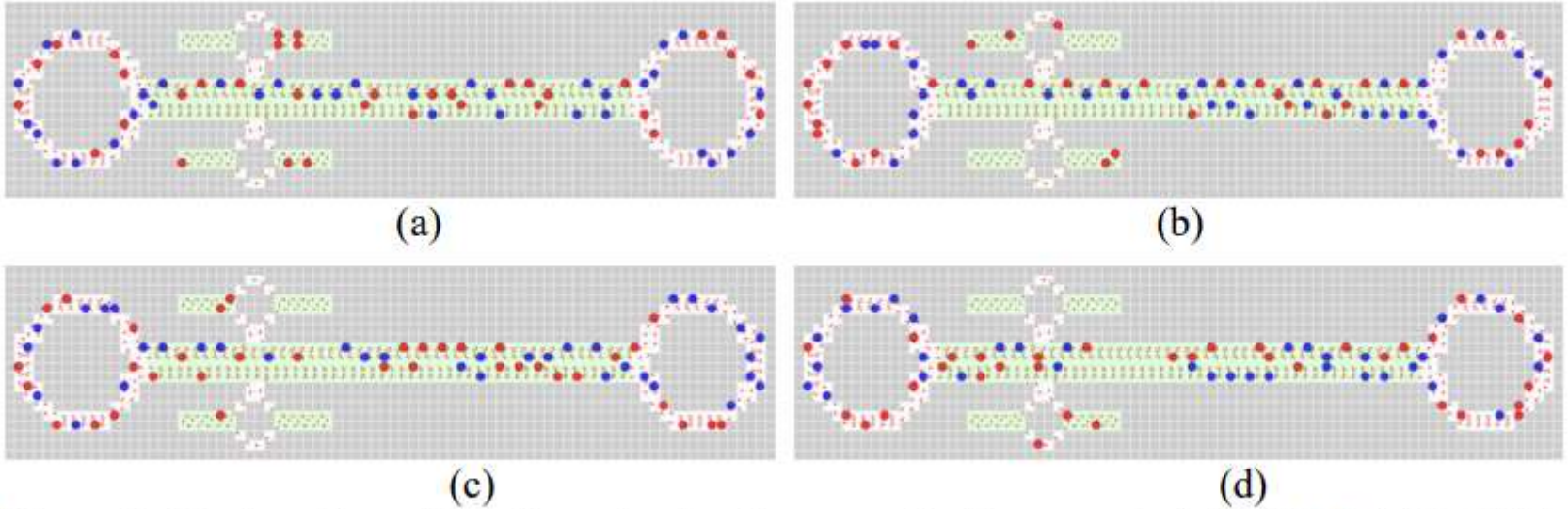


Figure 4. Final configuration of agents, about one month, for scenario (a) 0, (b) 1, (c) 2, (d) 3.

Arriving at destination vs visiting rest area

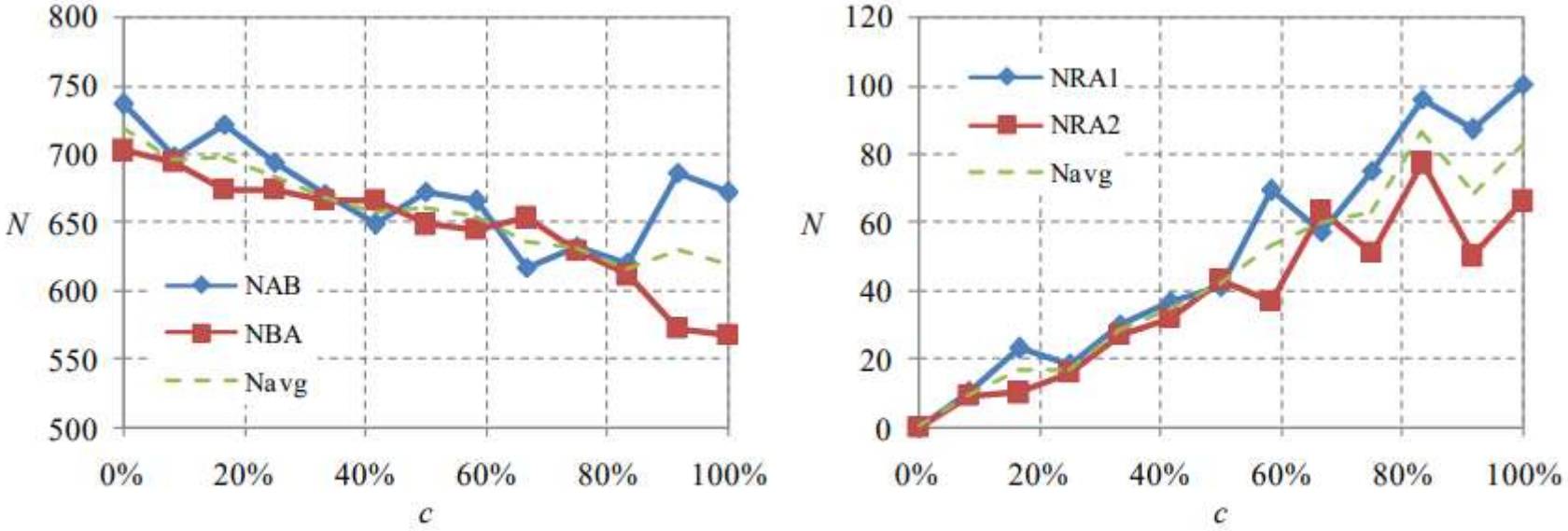


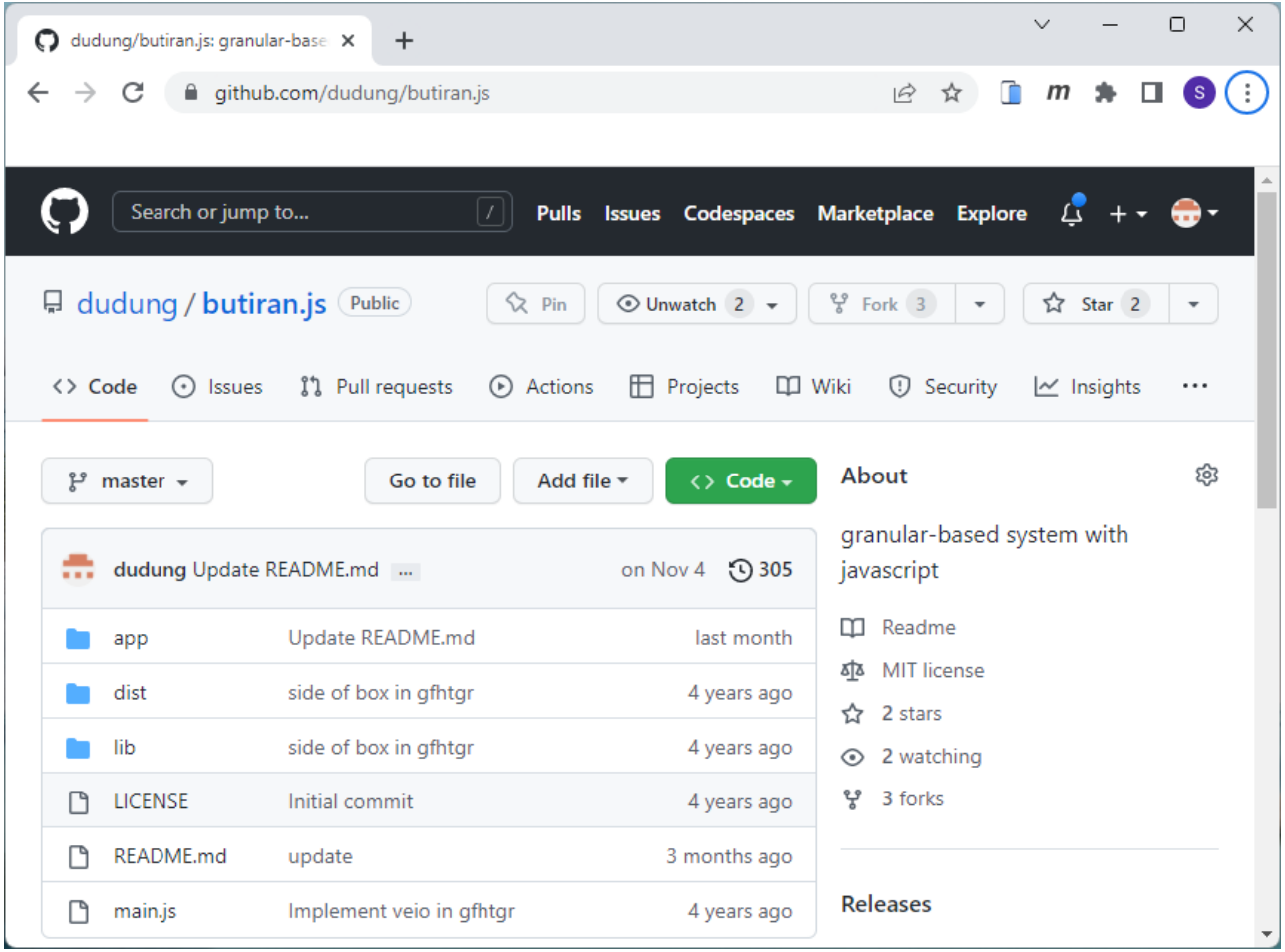
Figure 7. Monthly number of agents as function of fraction of the red agents c.

Which rest area (emergent pattern)

- Figure 7 (right) shows that nearest rest area (NRA1) always has higher value than the farther one (NRA2), where this distance is seen from the city where the agents are coming from.
- It is natural that when agents need to use a rest area, it will choose the nearest one.

The code: butiran.js

GitHub


dudung/butiran.js: granular-base
github.com/dudung/butiran.js
Search or jump to...
Pulls
Issues
Codespaces
Marketplace
Explore
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Public
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2 stars
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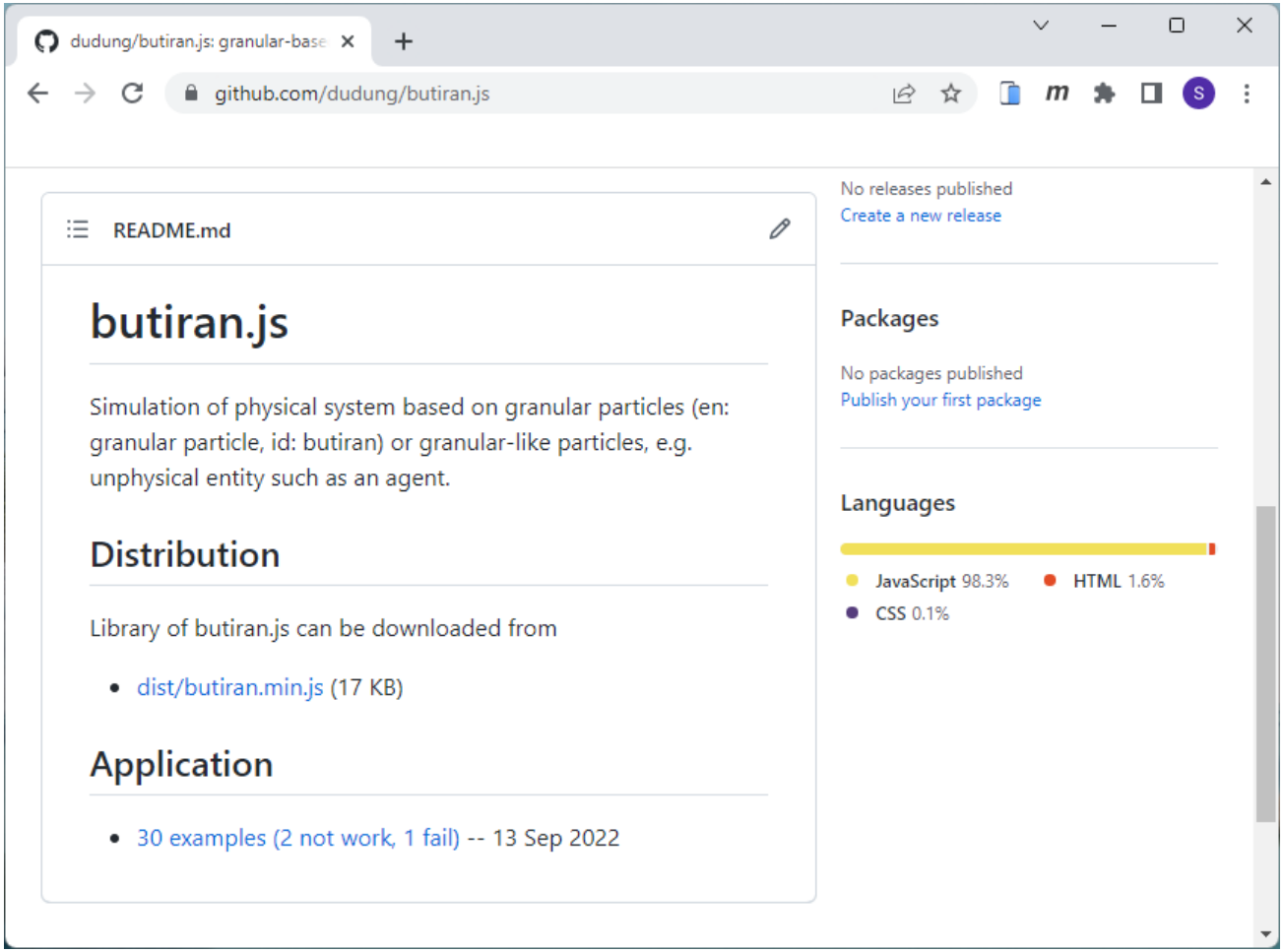
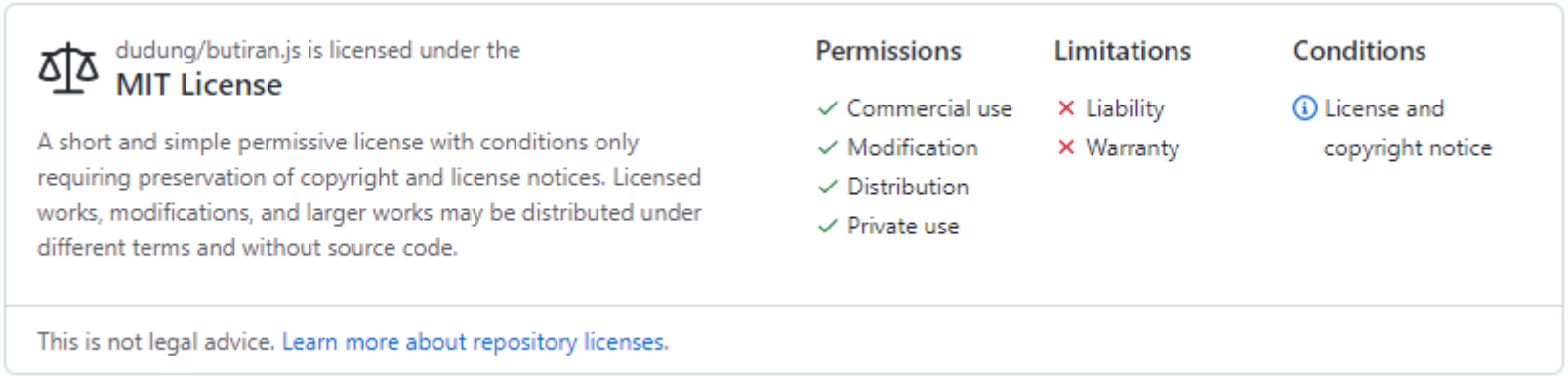
Releases


dudung/butiran.js: granular-base
github.com/dudung/butiran.js
README.md
butiran.js
Simulation of physical system based on granular particles (en: granular particle, id: butiran) or granular-like particles, e.g. unphysical entity such as an agent.
Distribution
Library of butiran.js can be downloaded from
dist/butiran.min.js (17 KB)
Application
30 examples (2 not work, 1 fail) -- 13 Sep 2022
No releases published
Create a new release
Packages
No packages published
Publish your first package
Languages
JavaScript 98.3%
HTML 1.6%
CSS 0.1%

Link

- url https://github.com/dudung/butiran.js
- It is open source.
- You can use and modify it.



Terima kasih

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